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A Portable Endstation for Analytical X-ray Microscopy Using Soft X-ray Synchrotron Radiation

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Soft X-ray microscopy enables the investigation of samples from life science and material science research topics with a resolution down to the tens of nanometer range. For biomedical samples the water window in between the K absorption edges of carbon and oxygen provides a penetration depth of up to 10 µm and a natural contrast between water and organic molecules [1]. Hence, these samples can be investigated in their almost natural state.

AnImaX (Analytical Imaging with X-rays) is a microscopy endstation for this soft X-ray spectral range deployable at synchrotron radiation facilities. Therefore, the instrument combines different imaging and detection methods. Since the AnImaX endstation is a portable instrument, it can be called an X-ray microscope on-demand. It has been initially built for the XUV variable polarization beamline P04 at PETRA III in Hamburg, but it is possible to adapt the endstation at other beamlines [2]. The setup and the alignment of the optical components to the X-ray beam usually takes up to 12 hours, including a resolution test using a Siemens star test pattern.

The setup of the AnImaX endstation includes a transmission X-ray microscope (TXM) for full-field imaging. The setup has been used for imaging of dynamic magnetic nanostructures [3]. For full-field imaging the sample is illuminated by a grating condenser with a diameter of 1 mm, consisting out of 940 diffraction gratings, which are arranged in circles around a central stop. This setup allows the homogenous illumination of a 20 µm spot on the sample, and is favorable for the use at undulator beamlines. For the image acquisition a tungsten zoneplate with an outer zone width of 50 nm in combination with an Andor IKon-L 936 X-ray camera with 2048 x 2048 active pixels and a pixel size of 13.5 µm x 13.5 µm is used. With the use of a zone plate doublet instead of the grating condenser it is possible to acquire differential interference contrast images.

The endstation is capable to switch operation to a scanning transmission X-ray microscope (STXM). During the last beamtimes the instrument has been operated primarily in the scanning mode [4]. By use of a zoneplate with an outer zone width of 45 nm and a diameter of 333 µm the X-ray beam is focused onto the sample. For image acquisition the sample is moved through the focused beam either step by step or continuously. For the detection of the transmission signal a P43 phosphor screen is placed behind the sample, which is imaged with an Andor IXon3 860 camera with 128 x 128 pixels, a pixel size of 24 µm x 24 µm and a frame rate of 513 fps at full resolution. This configuration enables fast scanning of the sample. The use of a spatially resolved detector empowers the simultaneous acquisition of multiple imaging modes. By modifying the detectors response function accordingly, it is possible to get absorption contrast, differential phase contrast and darkfield images. In addition, the spatially resolving detector enables the usage of ptychographic methods.

During the scan the emission of characteristic fluorescence photons is recorded with an energy dispersive silicon drift detector (SDD). Thereby a detailed map of the elemental distribution is obtained. X-ray fluorescence detection can also open up the path to quantification with respect to laterally resolved elemental concentrations. The high solid angle of detection of the SDD (>1 sr) allows fast image acquisition in scanning mode. For specimen with a strong fluorescence signal dwell times per pixel of 5 ms are possible.

Currently the imaging capabilities of the instrument are enhanced in cooperation with Axilon. A sample rotation stage is added for tomography. Furthermore, for imaging radiation sensitive samples without structural changes from radiation damage, samples can be kept below -150°C with a miniaturized cryo sample mount mounted on the scanning stage. To avoid the formation of ice crystals, samples are vitrified in a plunge freezer and transferred into the vacuum chamber under cryo conditions.

Figure 1 shows the mechanical design of the end station including the cryo sample transfer system. For the transfer, vitrified samples are mounted in the transfer holder under liquid nitrogen in a separate work station. After inserting the sample in the cold stage, the transfer rod is retracted and the sample can be scanned for imaging without contact to the transfer mechanism. Both the cold stage and the warm interface are temperature controlled to avoid thermal drift. The sample scanning stage is mounted on a rotation table to acquire tomographic data sets. The cooling connection allows a rotation range of ±90°.

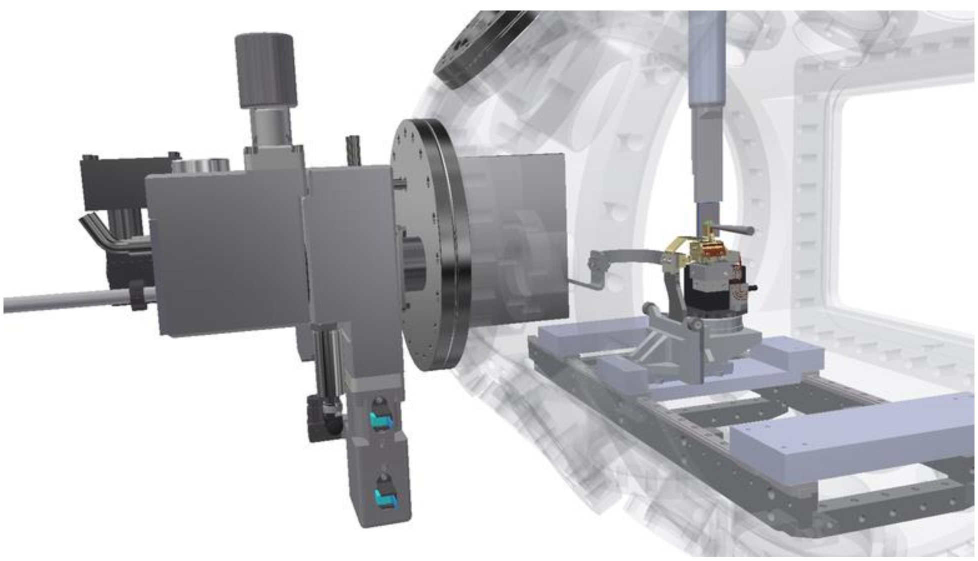

Figure. 1. View of the endstation design with main chamber, in-vacuum optics including cold stage, load lock and cryo transfer chamber. The focusing stage and the detector stage are not shown.

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